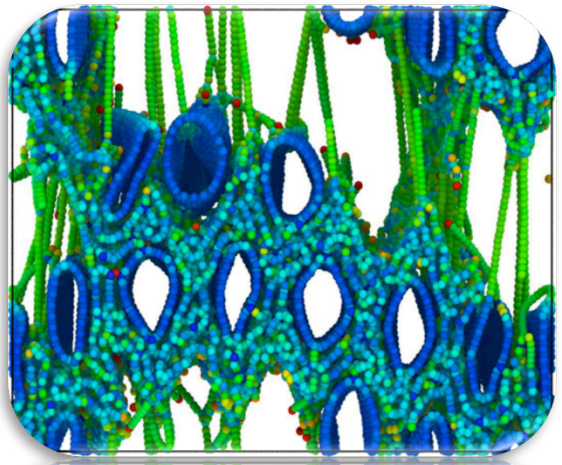
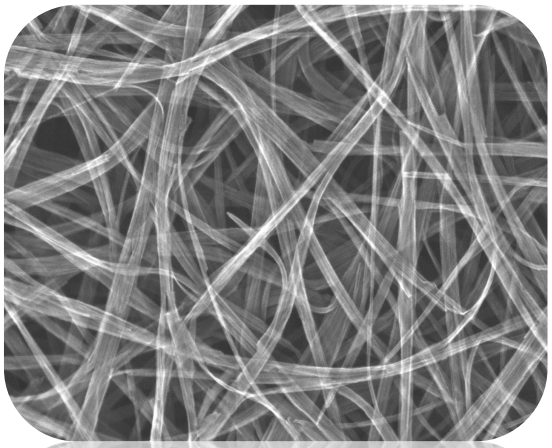
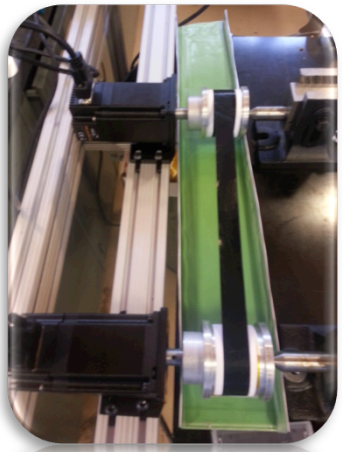
Structural Nanocomposites for Aerospace Applications

NASA/Orbital ATK Technical Interchange Meeting

Mia Siochi
May 19, 2015


NASA Structural CNT Team



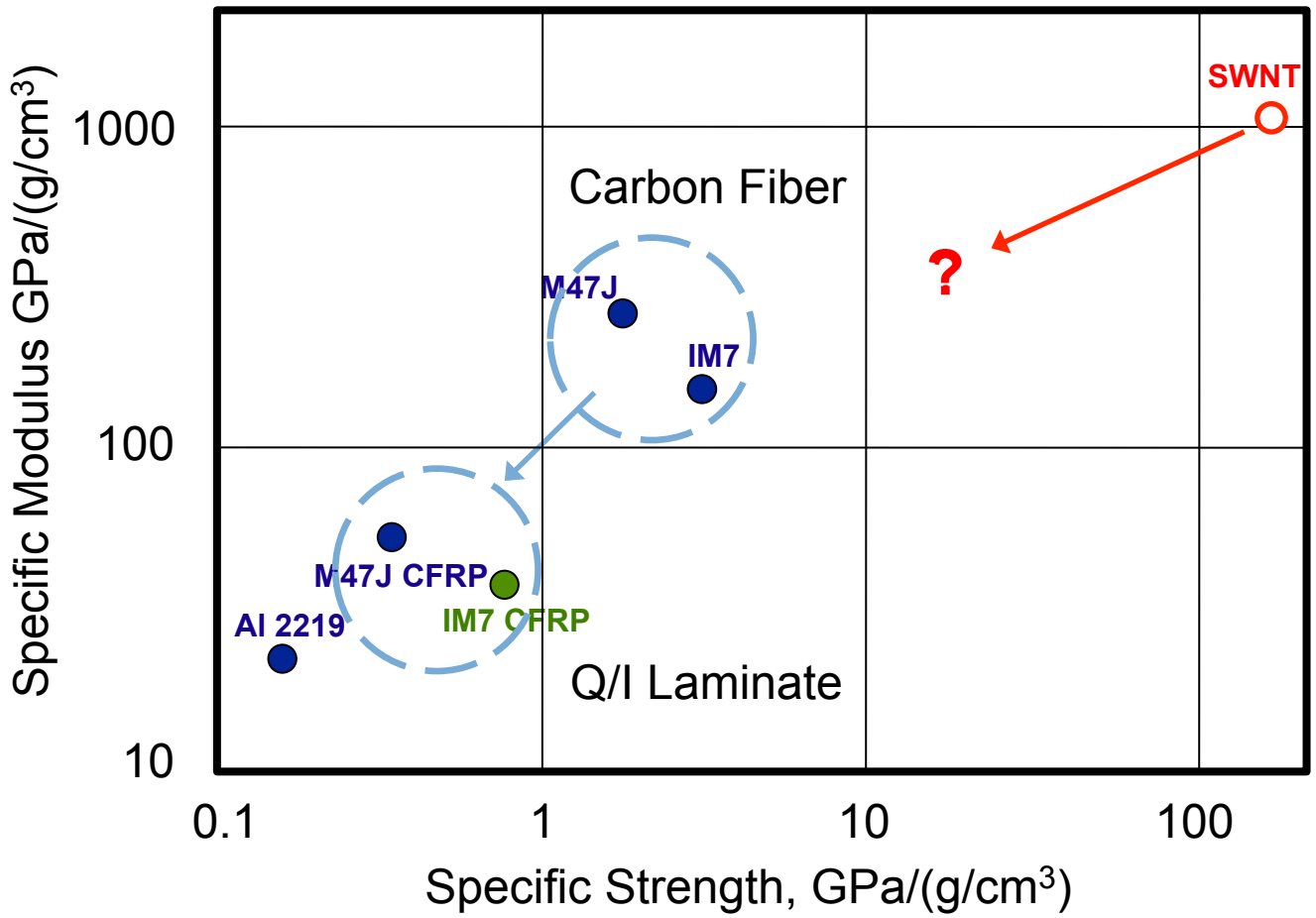
Langley Research Center

- **Computational Materials**
 - NASA LaRC
 - Kris Wise
 - Ben Jensen
 - Universities
 - Greg Odegard – MTU
 - Adri van Duin – PSU
- **Synthesis**
 - NASA GRC
 - Sandi Miller
 - Tiffany Williams
 - Marisabel Lebron-Colon
 - James Baker
 - NASA LaRC
 - John Connell
 - Joe Smith
 - Yi Lin
 - Material Suppliers
 - Nanocomp Technologies
 - General Nano
 - Universities
 - University of Cincinnati
 - Rice University
- **Processing**
 - NASA LaRC
 - Brian Grimsley
 - Bert Cano
 - Dennis Working
 - Sean Britton
 - Hoa Luong
 - Jae-Woo Kim
 - Godfrey Sauti
 - NASA GRC
 - Sandi Miller
 - Tiffany Williams
 - Universities
 - FSU
 - University of Cincinnati
- **Materials Characterization/ Testing**
 - NASA LaRC
 - Buzz Wincheski
 - Mike Czabaj
 - James Ratcliffe
 - Jae-Woo Kim
 - Yi Lin
 - Godfrey Sauti
 - Jennifer Carpena
- **Structural Mechanics & Design**
 - NASA LaRC
 - Steve Scotti
- **Systems Analysis**
 - NASA LaRC
 - Mark McMillin

Collaborative Partner:

AFOSR –Low Density Materials Program
PM: Dr. Joycelyn Harrison

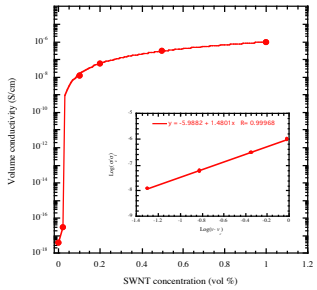
Why Structural Nanomaterials?

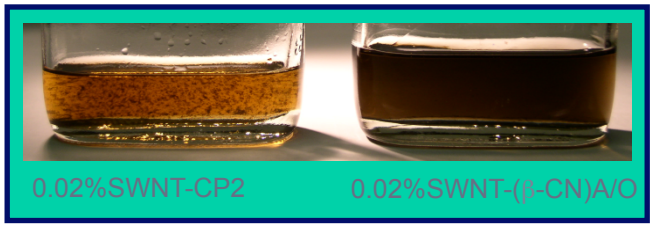


Harris, Shuart, Gray, NASA TM 211664, 2002

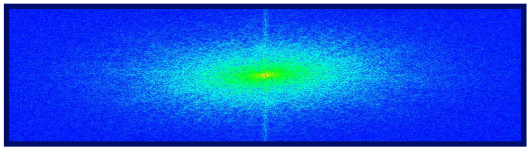
Highlights from Early Work: 1999 – 2008

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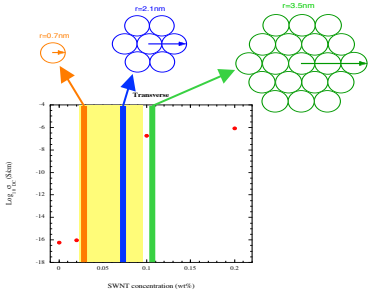




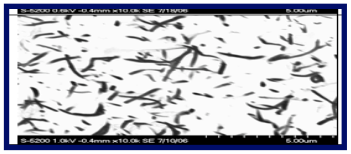
Observed Differences in Nanocomposite Solution Stability

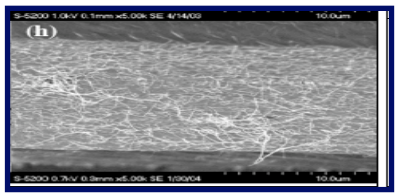


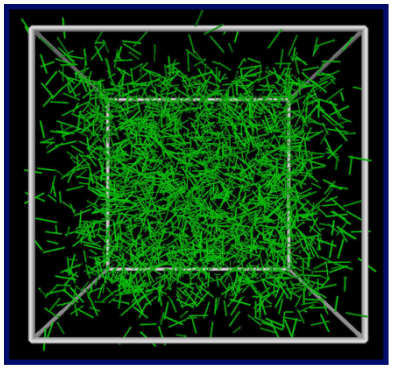
Fast Fourier Transform of HRSEM Image

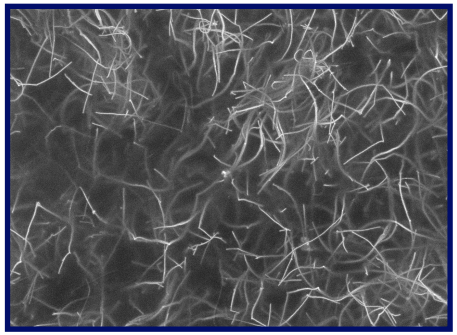


Measured Electrical Conductivity and Percolation Modeling





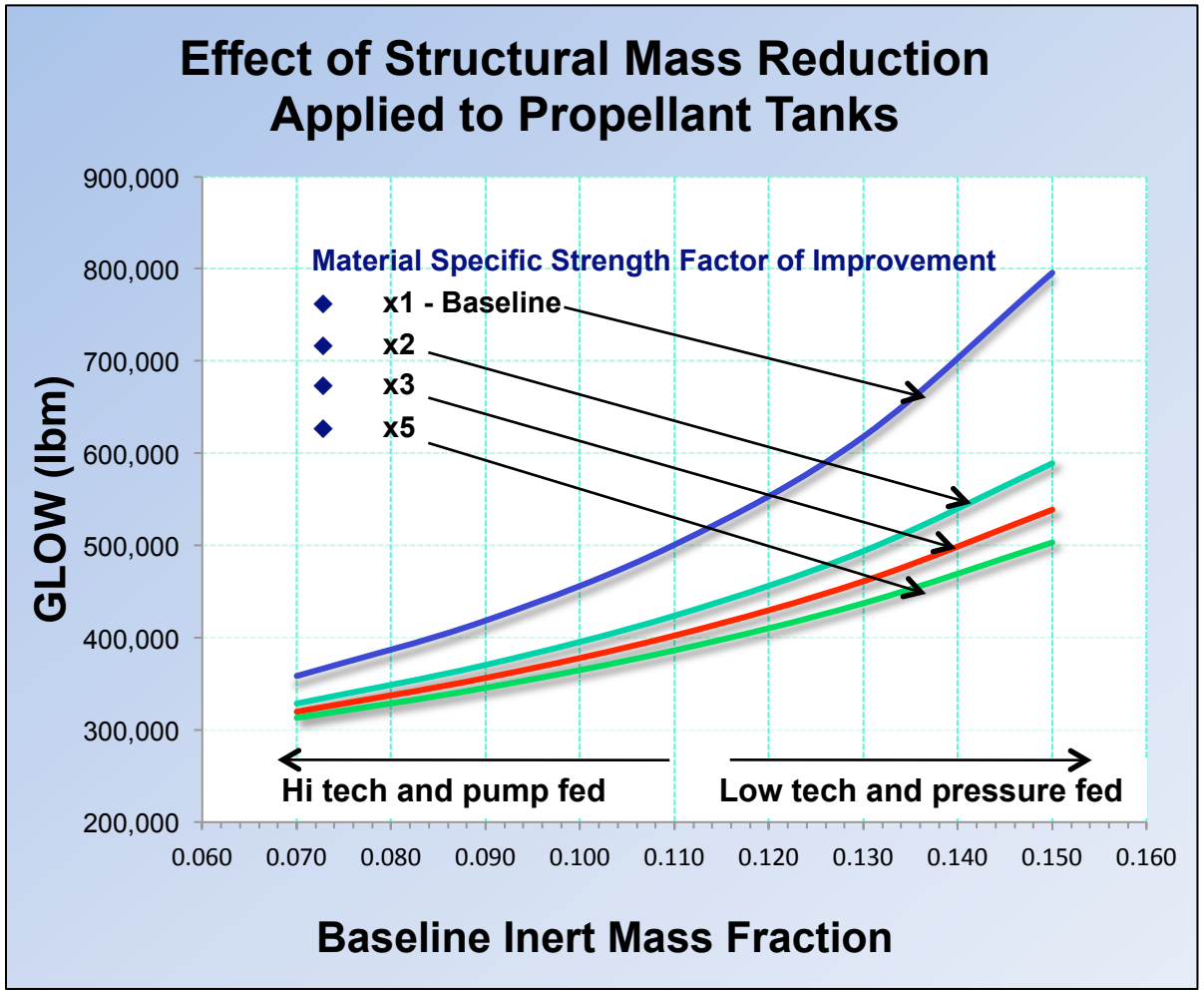




"Poly-transparent" Imaging

Potential System Weight Savings

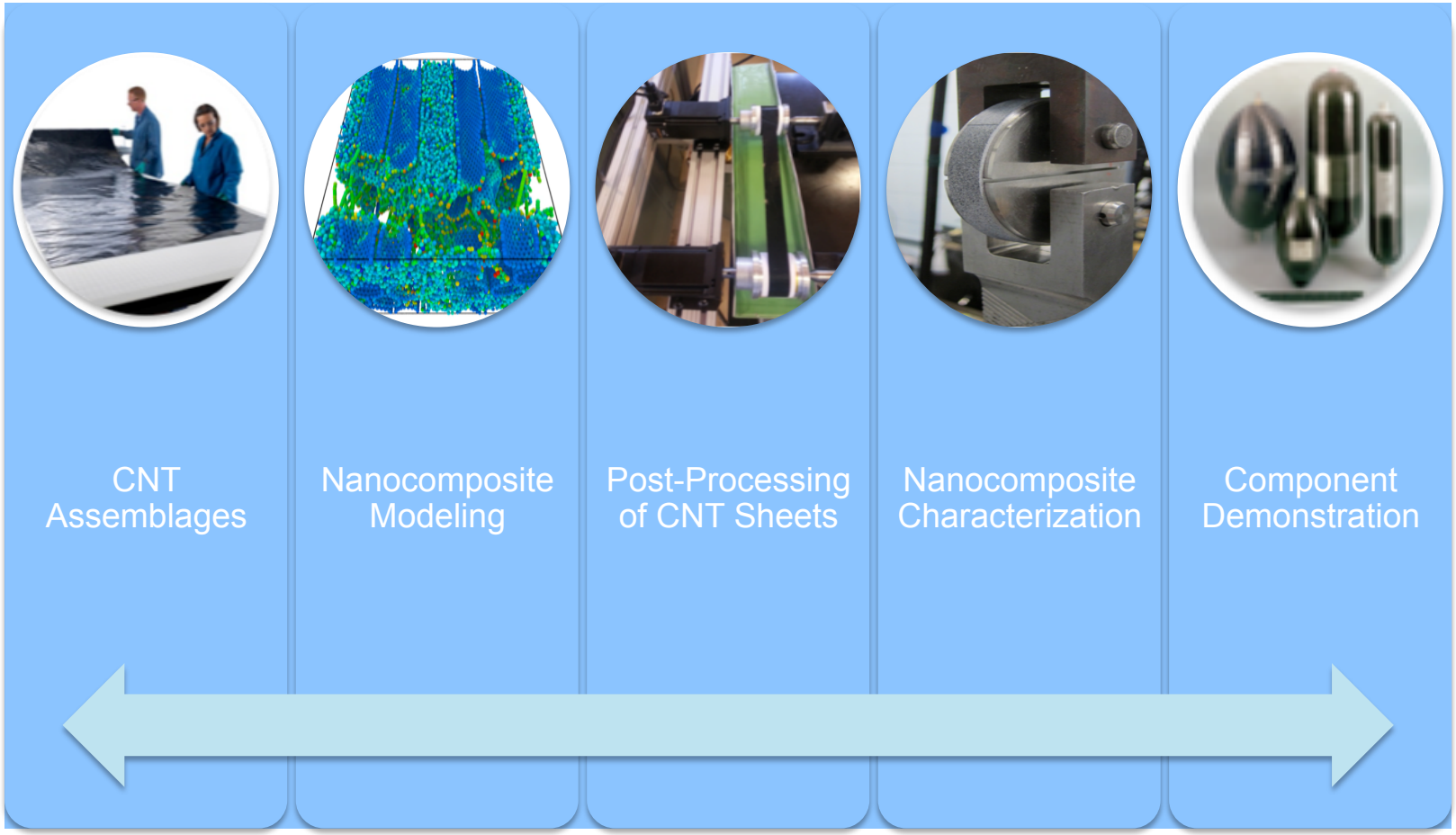
Two Stage to Orbit Launch Vehicle Concept



- Baseline Mass Fractions typical for existing cryogenic pump and pressure fed stages
- Weight savings applied to pressurized structures only
- Including other structures and subsystems may show increased benefit
- Low tech pressure fed systems show greatest benefit from reduced structures weight

Nanotechnology Project Spans Modeling to Component Demo

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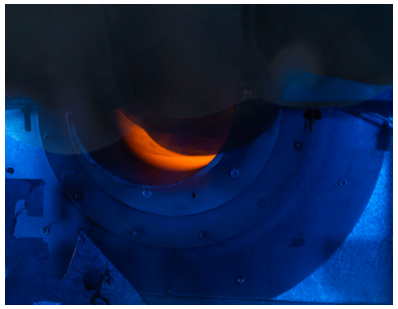
Project has adopted a comprehensive approach involving modeling, materials development, testing and characterization, and component level demonstration to accelerate materials development and mission transition

Materials SOA

Nanocomp Technologies

Langley Research Center

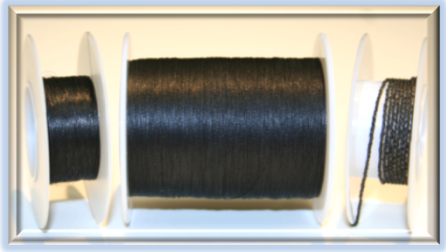
Non-Woven Textile



CNT Tape



CNT Yarn

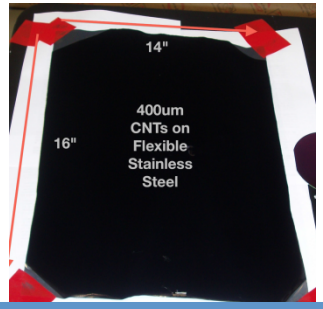


CNT Sheet

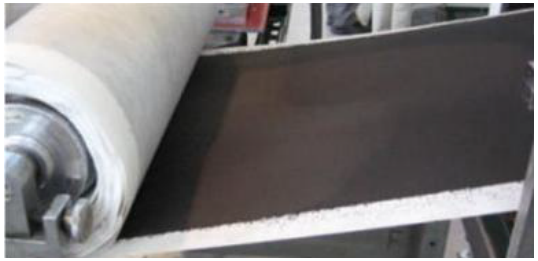


General Nano

Vertical Arrays

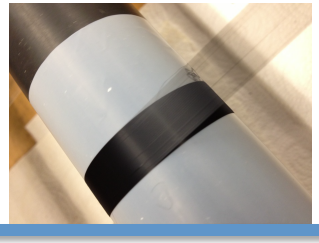


CNT Sheet

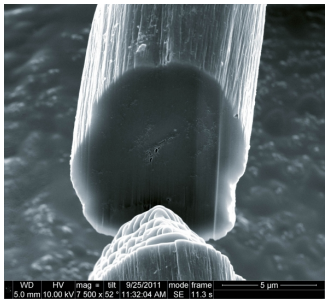


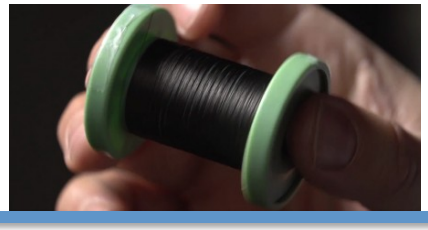
University of Cincinnati





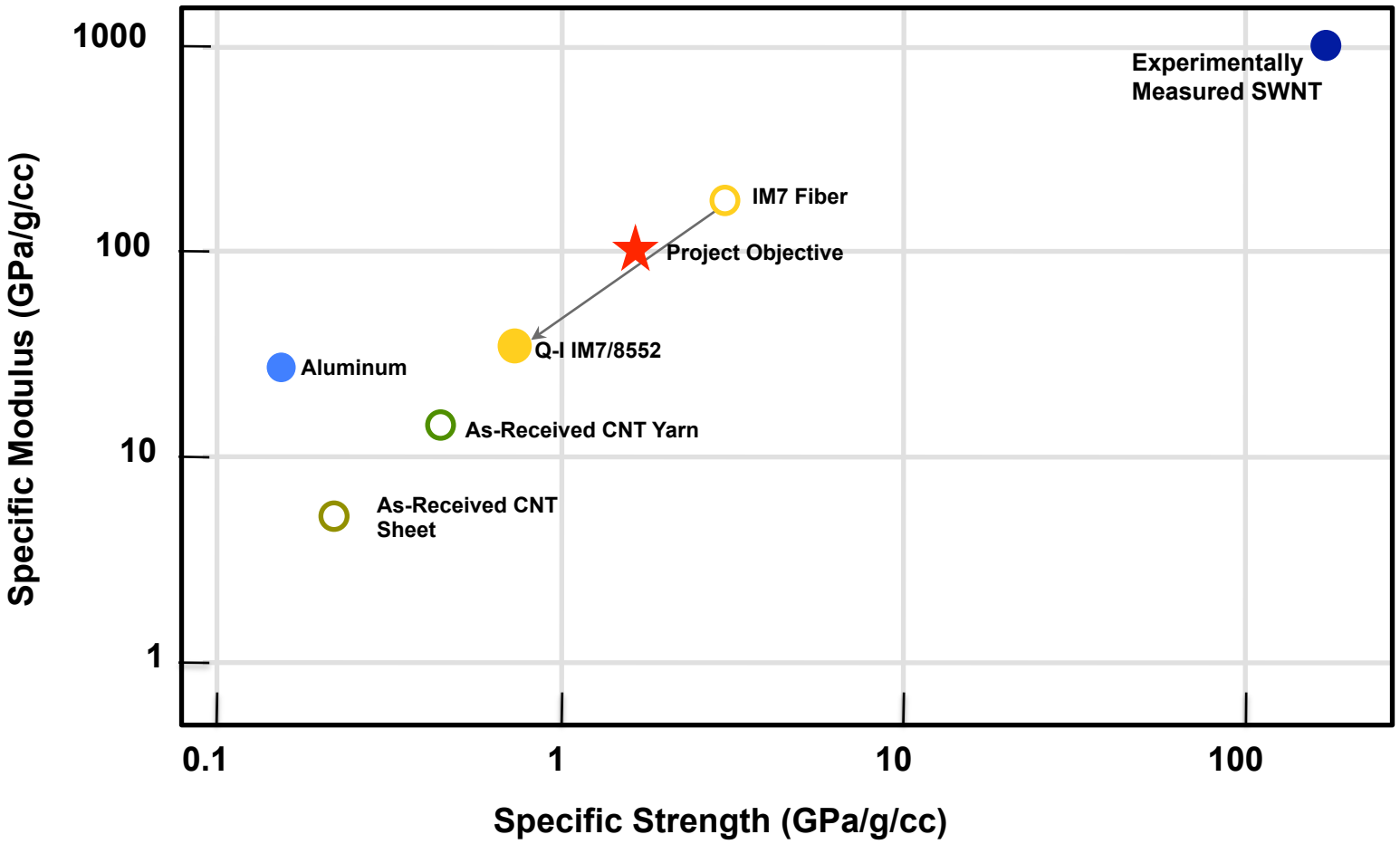
Rice University





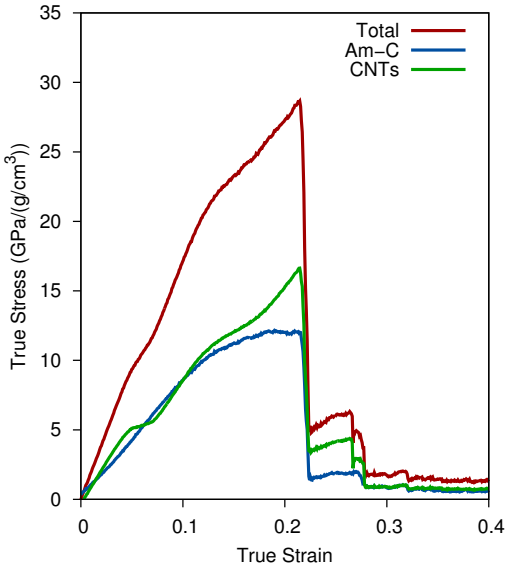
Nano to Macro Challenge

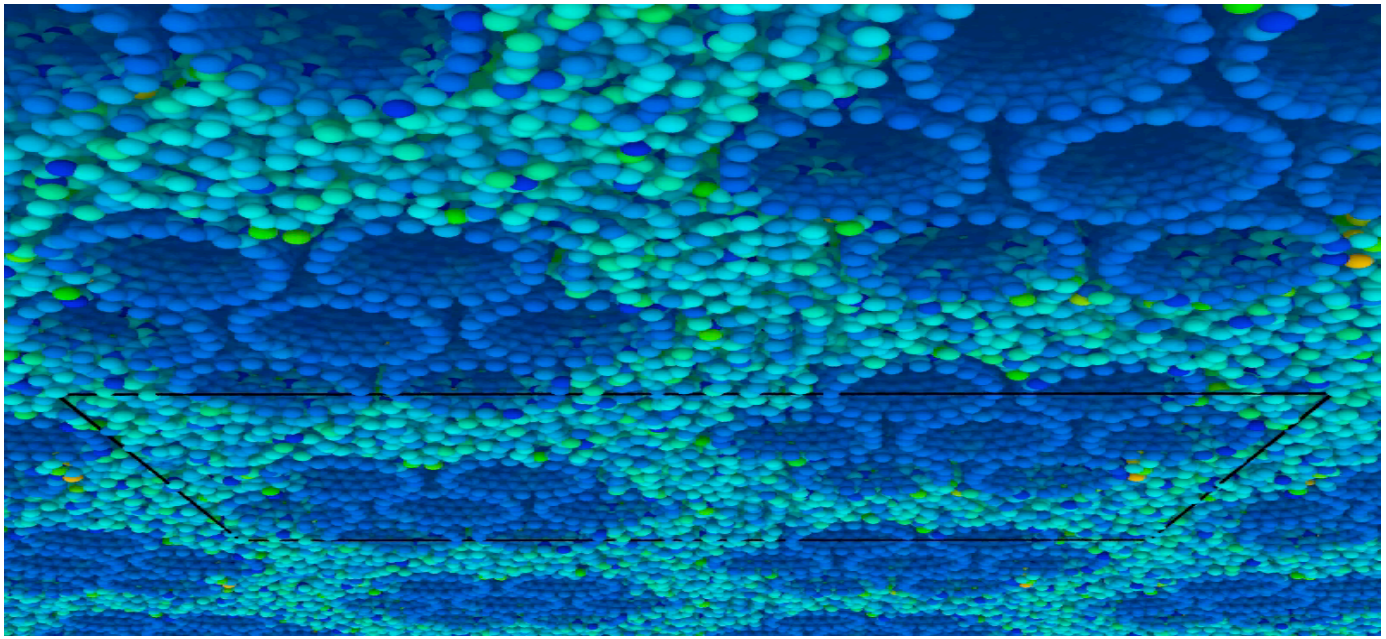
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- Available materials have starting mechanical properties inferior to other SOA materials.

Bundle Failure

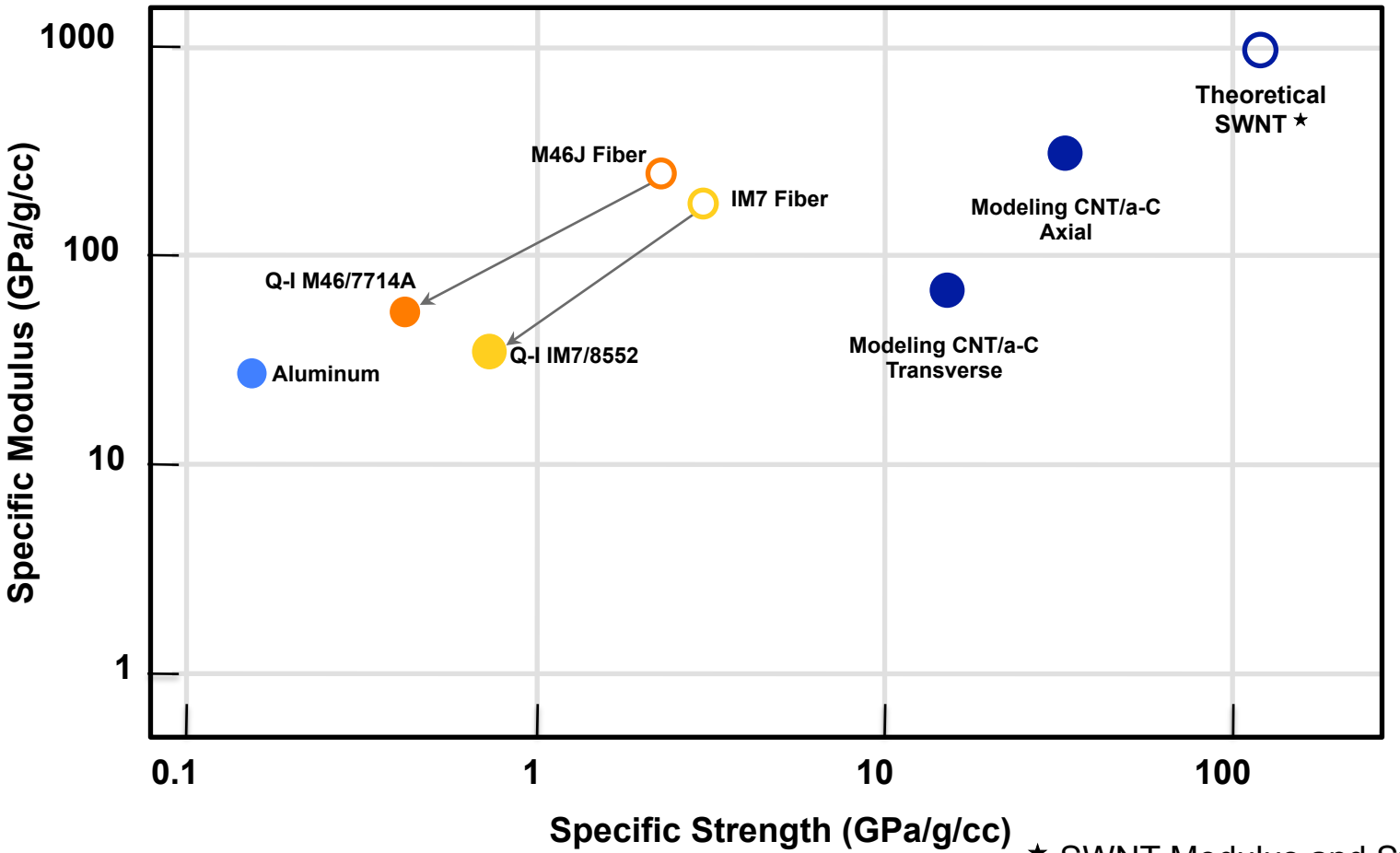




Modeling CNT Based Structural Materials

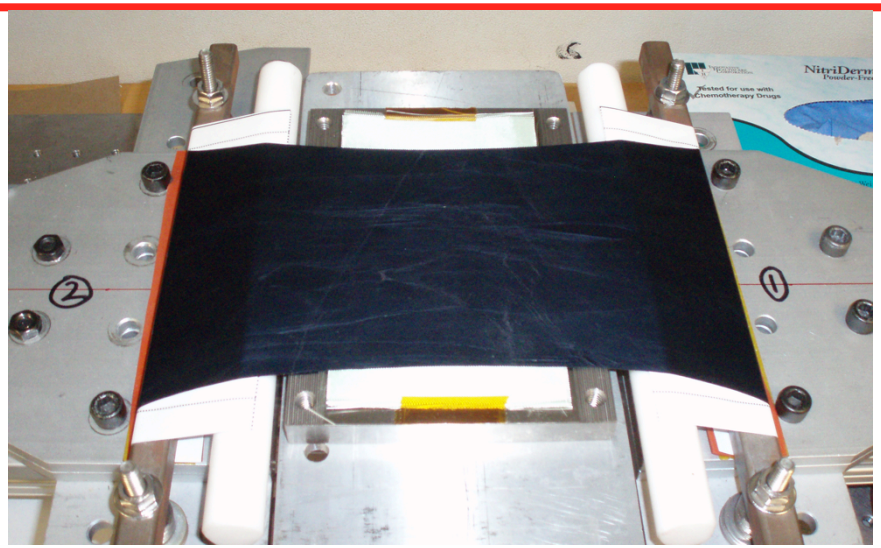
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Calculated Mechanical Properties in Context

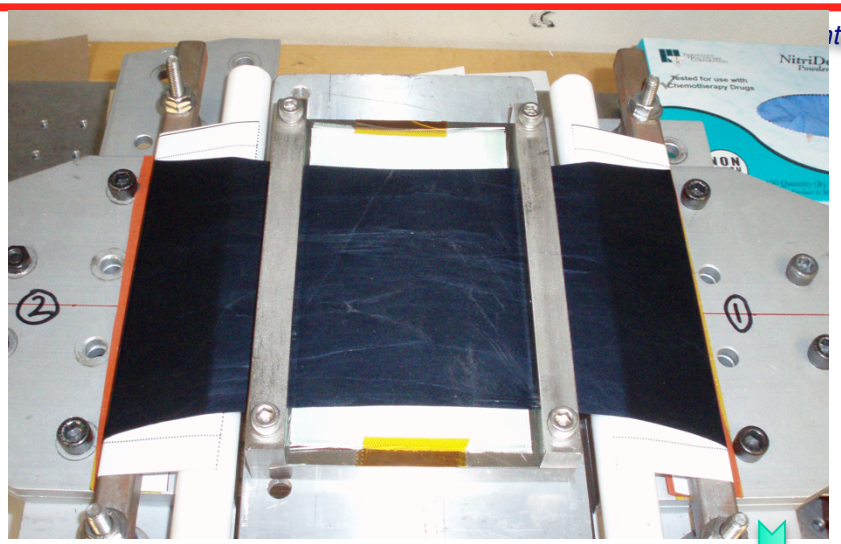


★ SWNT Modulus and Strength unscaled due to ambiguity in density

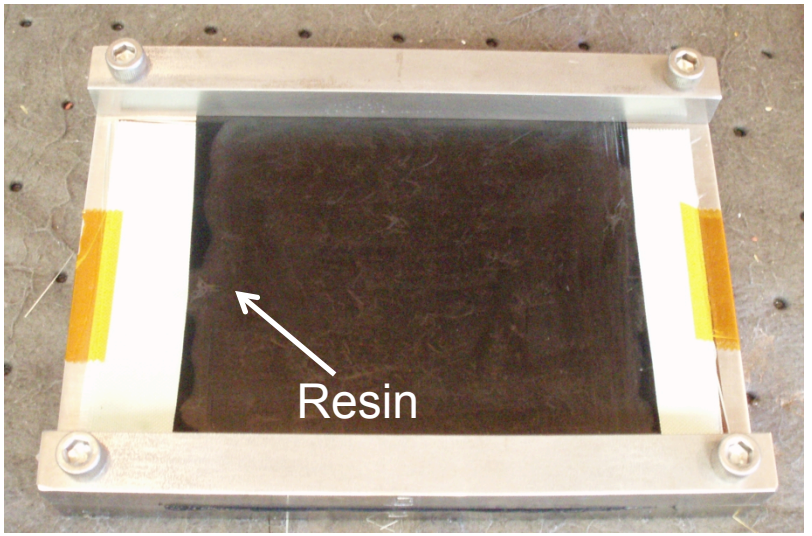
CNT Composite Procedure



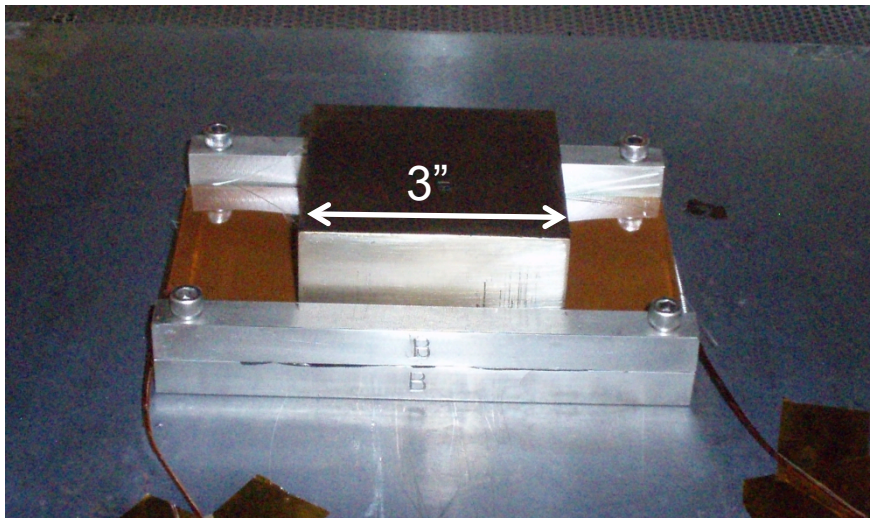
Stretched



Clamped

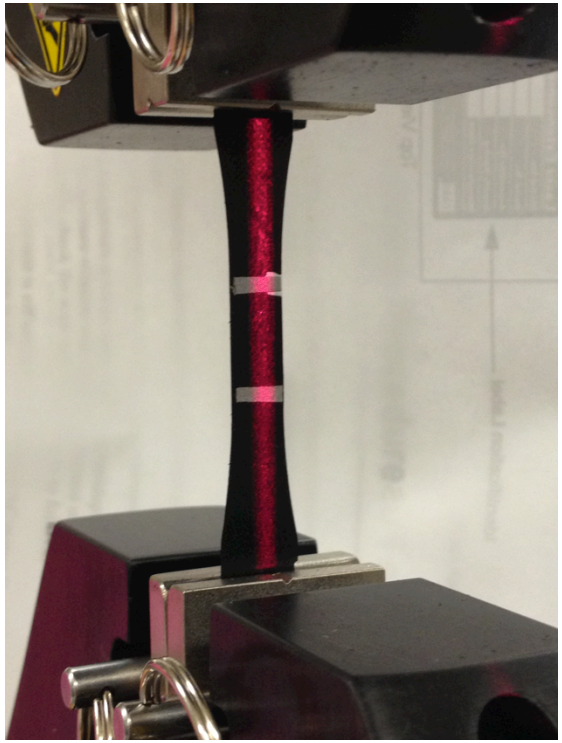


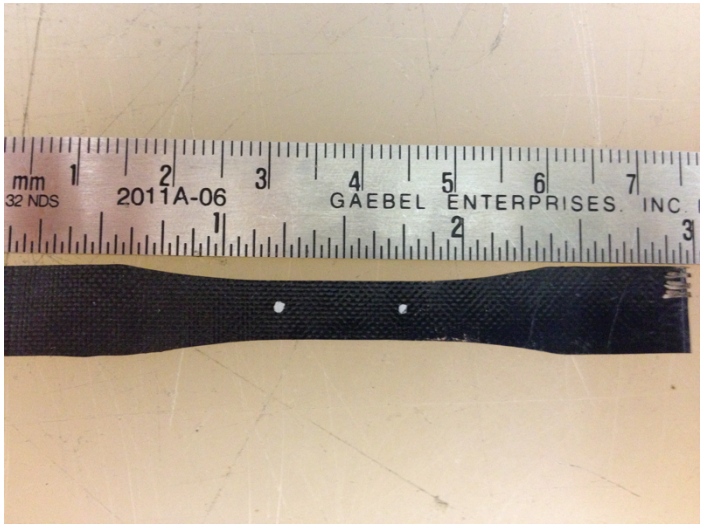
Coated with Resin Solution



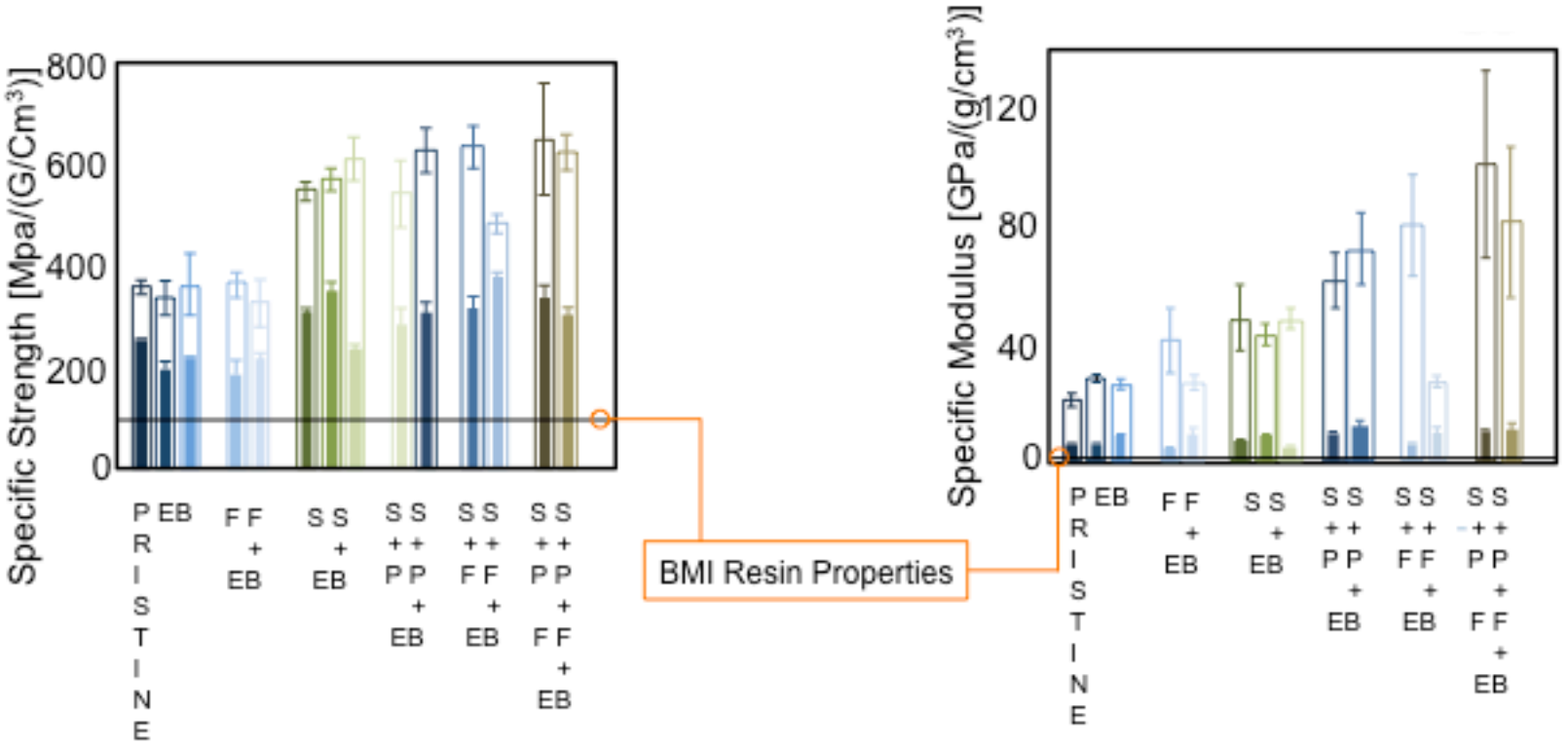
Cured while Clamped

CNT Composite Tensile Testing





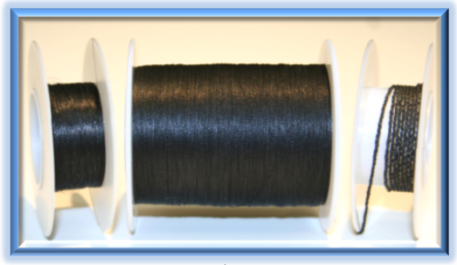
Influence of Post-Processing on CNT Sheet Composite Properties



Pristine:	PristineCNT sheet (Lot#70044-Acetone treated)
EB:	EB (40 min)
EB:	EB (90min)
F:	m-CPBA Functionalized
F + EB	m-CPBA Functionalized +EB (90min)
S	Stretched (41%)
S + EB:	Stretched (49%) +EB (90min)
	EB (90min) Stretched (20%)
S + P:	Stretched (46%) + purified
S + P + EB:	Stretched (33%) + purified + EB (90min)
S + F:	Stretched (43%) + m-CPBA Functionalized
S + F + EB:	Stretched (43%) + m-CPBA Functionalized + EB (90min)
S + P + F:	Stretched (46%) + purified + m-CPBA Functionalized
S + P + F + EB:	Stretched (33%) + purified + m-CPBA Functionalized + EB (90min)

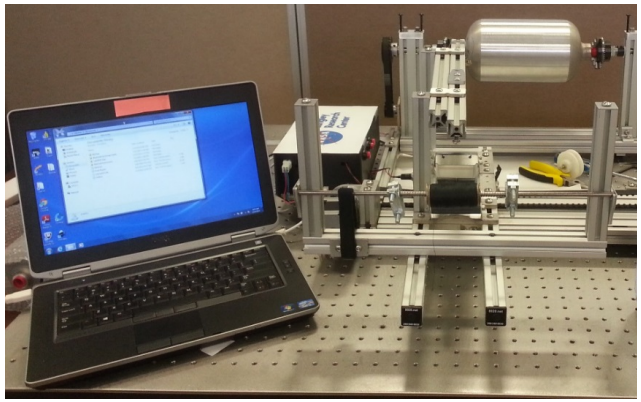
CNT Yarn to CNT COPV

CNT Yarn

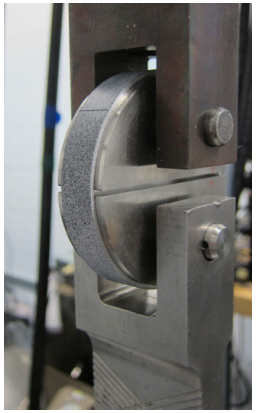


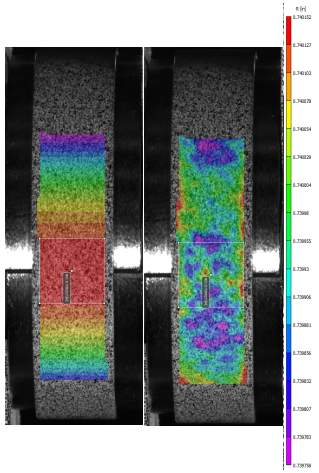
CNT Yarn COPV

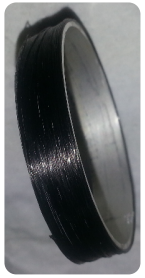




Solution Infiltration and Wet Winding of CNT Yarn



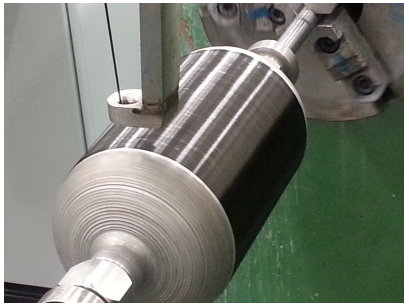




CNT Yarn Composite Wound Rings

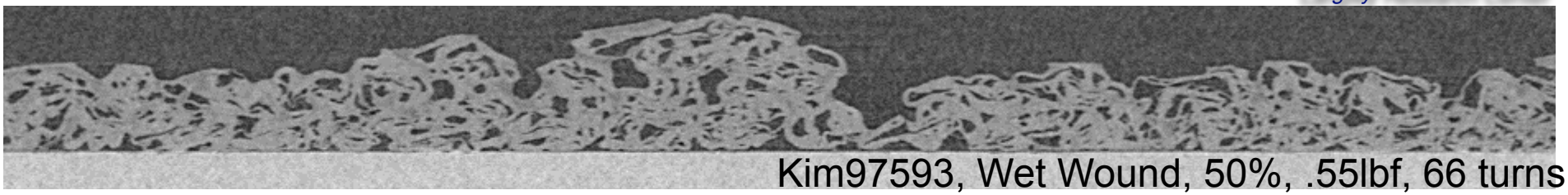


Variable Temperature Mechanical Testing

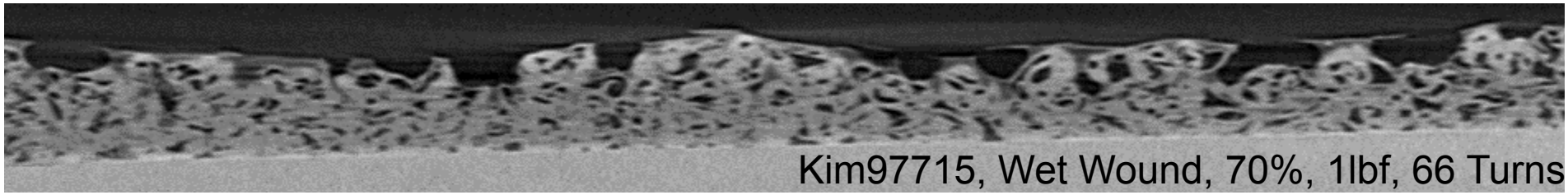


Commercial Scale Winding

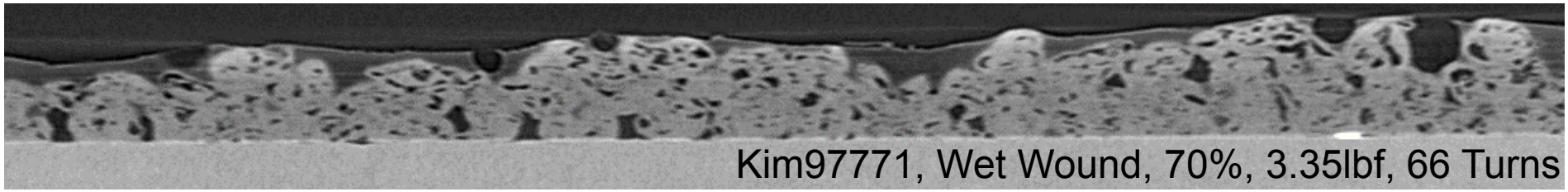
Characterization of Wound CNT Composites



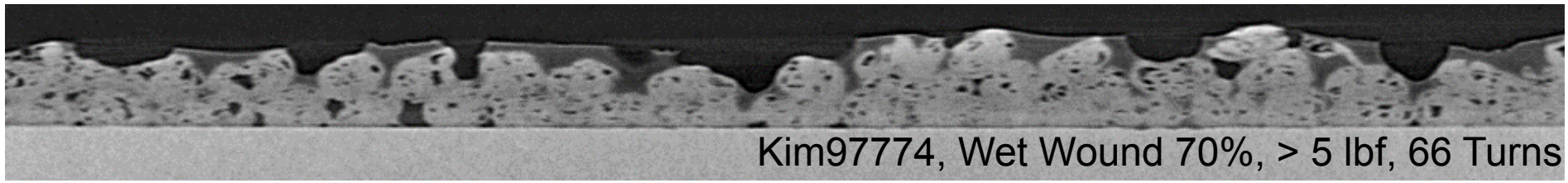
Kim97593, Wet Wound, 50%, .55lbf, 66 turns



Kim97715, Wet Wound, 70%, 1lbf, 66 Turns

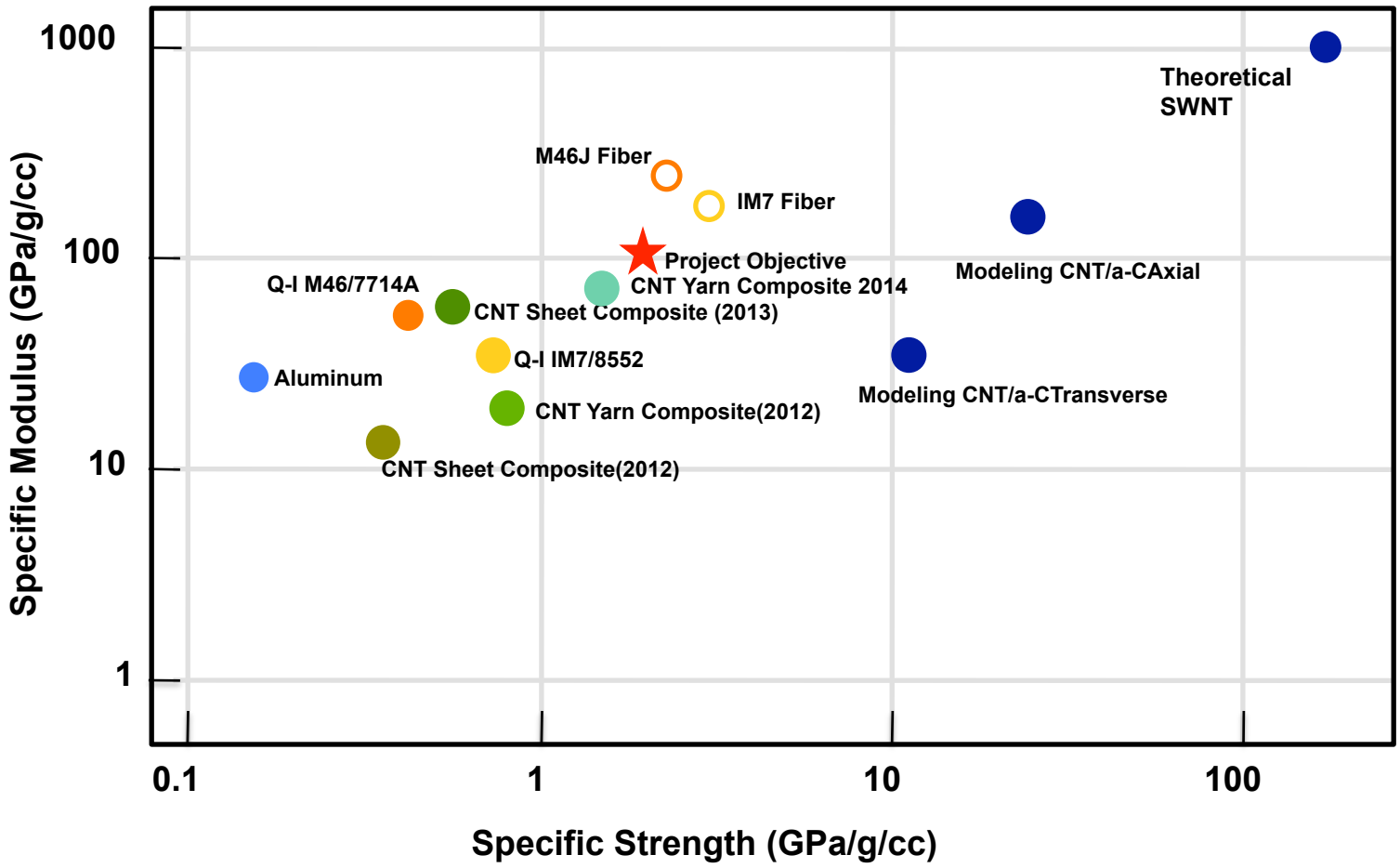


Kim97771, Wet Wound, 70%, 3.35lbf, 66 Turns



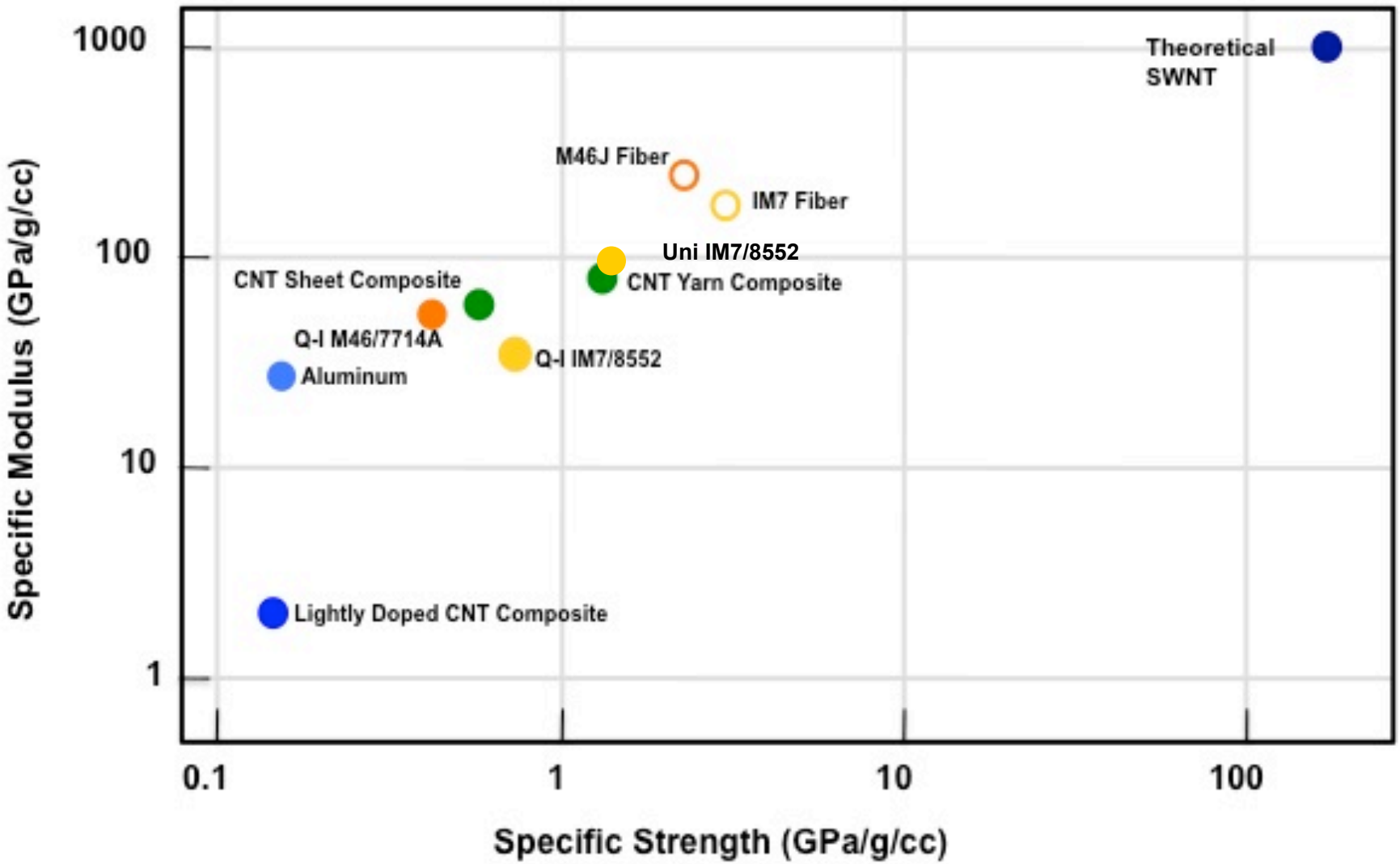
Kim97774, Wet Wound 70%, > 5 lbf, 66 Turns

Status – End of FY 14

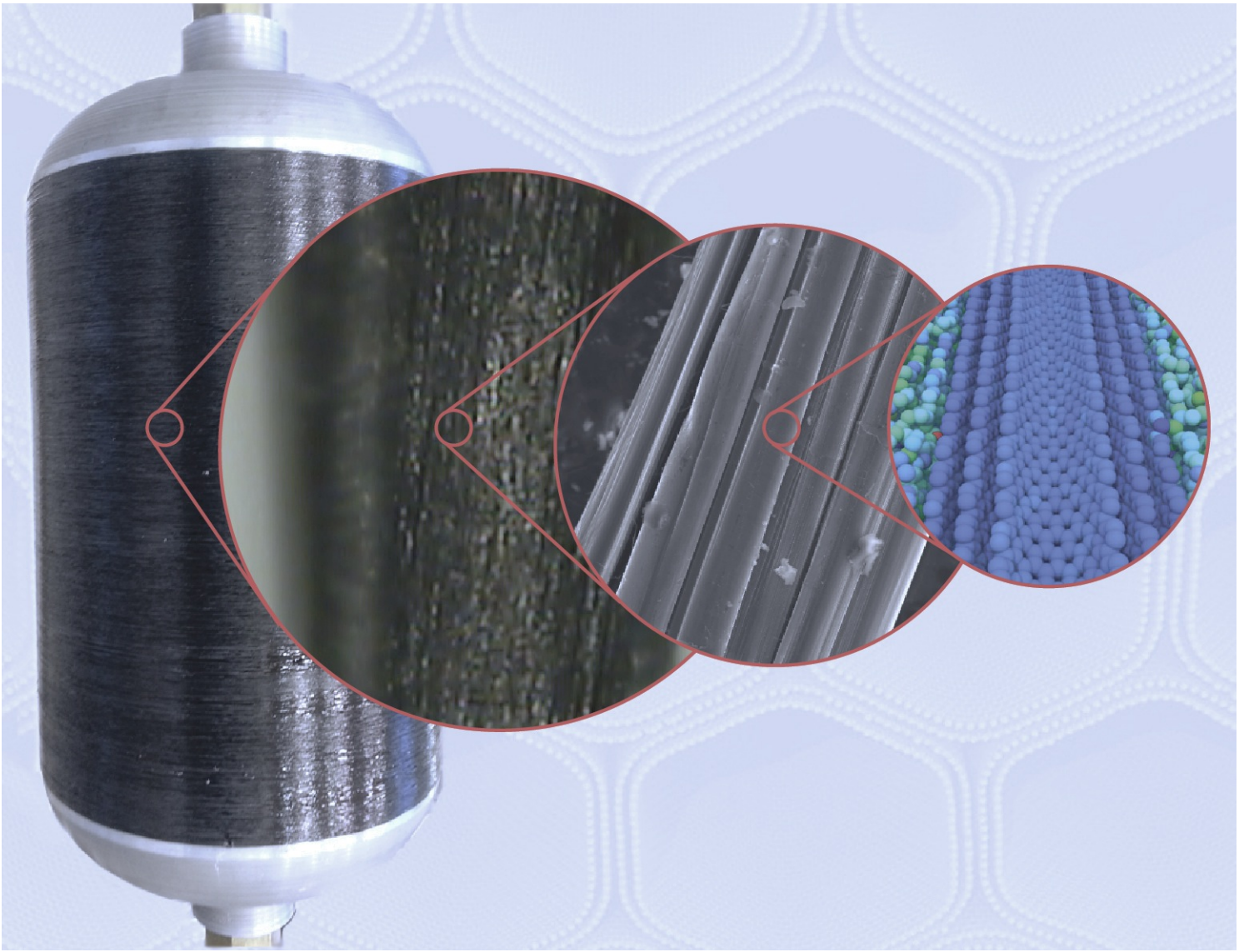


How is Structural Nano Different?

Langley Research Center

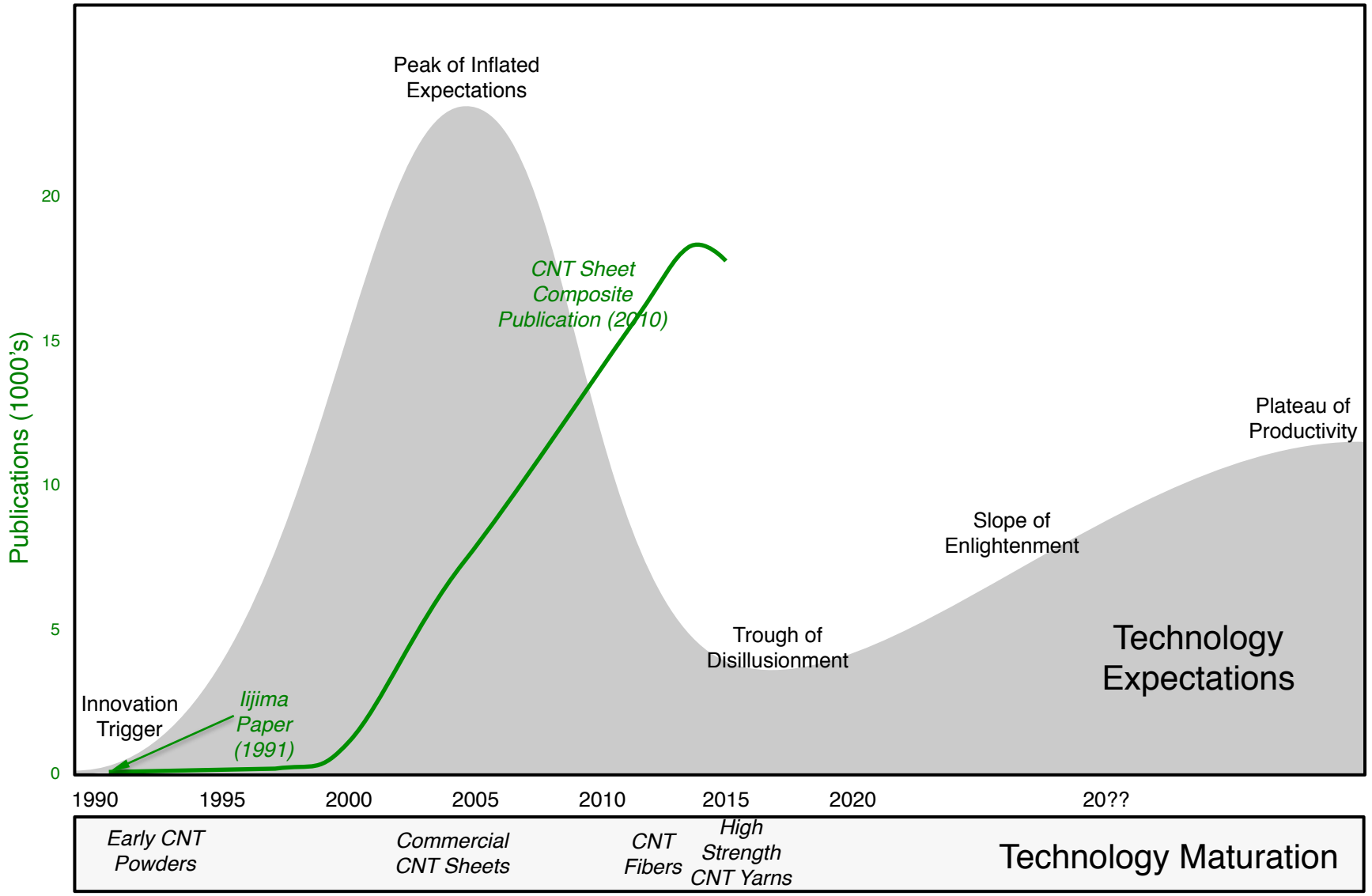


Accelerated Technology Maturation



Technology Tipping Point

Langley Research Center



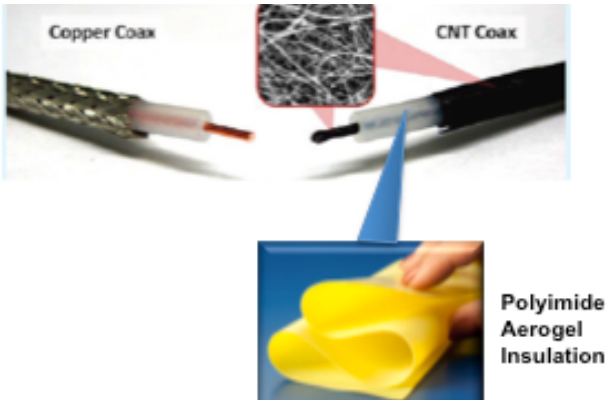
CNT/Aerogel Wires and Cables

- **OBJECTIVE: Reduce the mass and improve the fatigue resistance of power and data cables**
- **APPROACH: Utilize carbon nanotube conductors and ultralightweight aerogel insulation to reduce cable mass and improve fatigue resistance**
 - Employ intercalation chemistries to enhance electrical properties
 - Develop processing methods to apply aerogel insulation
 - Characterize electrical and thermal properties and cable durability
- **IMPACT:**

>70% reduction in data cable mass

>50% reduction in power cable mass

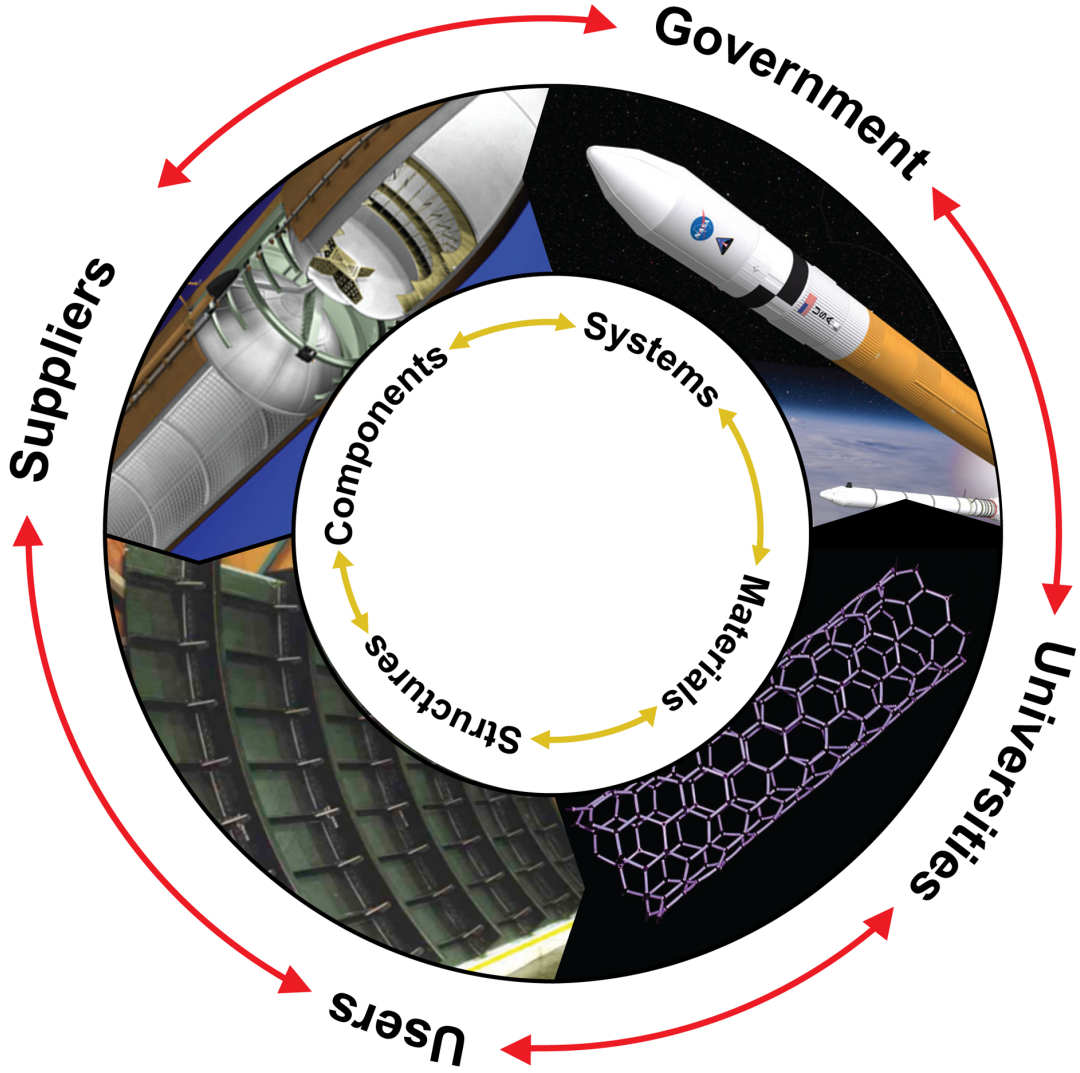
Glenn Research Center



Use of carbon nanotube conductors and ultralightwieght polymer aerogel insulation could reduce the mass of data cables by >70%.

- **FY2014 MAJOR ACCOMPLISHMENTS:**
 - ✓ **Improved electrical conductivity of CNT wires to 98 kS/cm**
 - ✓ **Demonstrated dip coating of polyimide aerogels onto CNT wires**

Accelerate Technology Maturation with Multidisciplinary Approach



Thank You

Langley Research Center

